IRRIGATION SYSTEM COSTS AND PERFORMANCE IN THE SAN JOAQUIN VALLEY

Prepared under contract
for the Federal-State

San Joaquin Valley
Drainage Program

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This report presents the results of a study conducted for the Federal-State Interagency San Joaquin Valley Drainage Program. The purpose of the report is to provide the Drainage Program agencies with information for consideration in developing alternatives for agricultural drainage water management. Publication of any findings or recommendations in this report should not be construed as representing the concurrence of the Program agencies. Also, mention of trade names or commercial products does not constitute agency endorsement or recommendation.

The San Joaquin Valley Drainage Program was established in mid-1984 as a cooperative effort of the U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, U.S. Geological Survey, California Department of Fish and Game, and California Department of Water Resources. The purposes of the Program are to investigate the problems associated with the drainage of irrigated agricultural lands in the San Joaquin Valley and to formulate, evaluate, and recommend alternatives for the immediate and long-term management of those problems. Consistent with these purposes, Program objectives address the following key areas: (1) Public health, (2) surface- and ground-water resources, (3) agricultural productivity, and (4) fish and wildlife resources.

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EXECUTIVE SUMMARY

Irrigation system performance and costs have been quantified to enable comparison of costs and benefits of improving irrigation efficiency. The costs and efficiencies have been categorized by three levels of management intensity (low, medium, and high), and for principal crops and irrigation technologies used in the San Joaquin Valley.

Different management levels may represent different irrigation system hardware for a particular irrigation technology as well as different administration and labor effort. Table 1 (page 2) illustrates the systems used to represent each irrigation method and management level.

Irrigation efficiency has been characterized by the following distribution fractions:

- Beneficial use (BU)
- Deep percolation (DP)
- Uncollected runoff (UR)
- Evaporation loss (EL)

The sum of these fractions for a particular management level and technology is always unity. Table 2 (page 8) gives the distribution for the array of irrigation technologies and management levels. It is assumed that distribution fractions are independent of crop type.

Component costs have been quantified for each technology and management level including:

- Capital (purchasing/installing)
- Maintenance
- Pumping (operation)
- Labor
- Administration (scheduling and implementation)

The total costs presented in Table 14 (page 36) are the sum of the costs mentioned above and represent the cost in dollars per acre per year required to achieve the corresponding distribution fractions.

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INTRODUCTION

The San Joaquin Valley Drainage Program has developed the Westside Agricultural Drainage Economics (WADE) model to facilitate evaluation of various policy options that could affect the volume and quality of agricultural drainage water in the west side of the San Joaquin Valley. This report presents irrigation system hydraulic performance characteristics and costs developed for WADE model operations. Included are irrigation systems commonly found in the study area as well as those that are used infrequently or not found at the present but compare favorably with existing systems in terms of reducing drainage volumes. This latter category is referred to as emerging technologies.

Because irrigation system performance and cost are related to management, not just physical components and configuration, three management levels are delineated. These relatively subjective levels are defined as follows:

- Low Management Level - minimum management effort, characterized by philosophies and activities often found in areas where irrigation water is inexpensive.
- Medium Management Level - typical management effort found in the Westlands Water District, where water is relatively expensive and water conservation programs have been active for many years.
- High Management Level - management effort required to obtain near potential irrigation efficiency for each given method. Few growers in the San Joaquin Valley practice this level of management.

Limited research-based data are available for the entire array of systems, crops, and management levels investigated. Consequently, this study relies substantially on nonresearch-oriented data sources such as local farmers, irrigation equipment vendors, and irrigation scheduling consultants, plus engineering judgment and experience. Data sources are listed in Appendixes A and B. Key assumptions made to facilitate this analysis are noted in this report.

IRRIGATION SYSTEMS

Irrigation systems in the San Joaquin Valley are as varied as the people who use them. Because of the multitude of irrigation products on the market and the innovative and resourceful nature of farmers, an infinite number of irrigation systems are in operation today, 11 of which have been selected for inclusion in the WADE model (Table 1).

Table 1
IRRIGATION METHODS

Abbreviation	Description of Method	Management Level	Description of System
F1-2	Half-mile furrows	Low	Siphon tubes
		Medium	Gated pipe
		High	Gated pipe
F1-2R	Half-mile furrows with tailwater return	Low	Siphon tubes
		Medium	Gated pipe
		High	Gated pipe
F1-4	Quarter-mile furrows	Low	Siphon tubes
		Medium	Gated pipe
		High	Gated pipe
F1-4R	Quarter-mile furrows with tailwater return	Low	Siphon tubes
		Medium	Gated pipe
		High	Gated pipe
BORD	Border strip	Low	Siphon tubes (1/2-mile runs)
		Medium	Pipeline with alfalfa valves (1/4-mile runs)
		High	Pipeline with alfalfa valves (1/4-mile runs)
BORD-R	Border strip with tailwater return	Low	Siphon tubes (1/2-mile runs)
		Medium	Pipeline with alfalfa valves (1/4-mile runs)
		High	Pipeline with alfalfa valves (1/4-mile runs)
SURG-2	Surge-controlled half-mile furrows with tailwater return	Low	Gated pipe with surge valve
		Medium	Gated pipe with surge valve
		High	Gated pipe with surge valve
SURG-4	Surge-controlled quarter-mile furrows with tail-water return	Low	Gated pipe with surge valves
		Medium	Gated pipe with surge valves
		High	Gated pipe with surge valves
HMS	Hand-move sprinklers	Low	4-inch x 30-foot laterals
		Medium	4-inch x 30-foot laterals
		High	4-inch x 30-foot laterals
DRIP	Surface drip	Low	Turnkey type system
		Medium	Turnkey type system
		High	Turnkey type system
LINEAR	Linear-move sprinklers	Low	1/2-mile linear system
		Medium	1/2-mile linear system
		High	1/2-mile linear system

Surface irrigation methods remain the most widely used in the San Joaquin Valley. Systems chosen to represent this category are half-mile furrows with and without tailwater return, quarter-mile furrows with and without tailwater return, and border strips with and without tailwater return. Systems selected to represent emerging technologies in the surface category are surge-controlled furrows with tailwater return on half- and quarter-mile runs.

Sprinkler irrigation is represented by two systems: hand-move sprinklers, which are fairly common, and linear move sprinklers, which are considered here as an emerging technology despite their proven effectiveness at other locations.

Finally, surface drip irrigation represents the drip irrigation method.

Any irrigation system can be operated with varying degrees of management. In some cases, however, it is most practical to assume that upgrading of the type of system used is inevitable as the management level of certain irrigation methods increases. Therefore, the types of systems used for low levels of management are typically very simple and often represent the minimum capital investment required to implement that irrigation method.

Costs and hydraulic performance characterizations are based on a conceptual design of each of the systems listed in Table 1. Each conceptual design includes the major system components required to irrigate a representative parcel assuming water is delivered to the upstream corner of the parcel under approximately 5 feet of head (Johnson, 1987). The representative parcel for all of the methods except the linear move sprinkler is a 160-acre square field or typical quarter-section parcel. The conceptual design for linear move sprinklers is based on a half-section (320-acre) system.

Each representative system is described below. Components of each system, including pipe size, are tabulated in the Capital Costs section of this report.

FURROW SYSTEMS

For the half-mile furrows under low management levels, the representative system consists of a single earth-lined head ditch and small-diameter siphon tubes to deliver water to the furrows. To benefit from medium and high levels of management, a single line of gated pipe replaces the head ditch.

For the quarter-mile furrows under low management, the representative system consists of an unlined head ditch at the top of the field and a second ditch running along the side

and across the center of the field, resulting in approximately 1.25 miles of head ditch. Siphon tubes deliver water from these head ditches to the furrows. For medium and high management levels, the head ditches are replaced with pipe: gatepipe across the head and center of the field, and plain or carry pipe along the side. The quarter-mile gated pipe system includes additional appurtenances such as valves and fittings.

The same tailwater return system is assumed to be used for both the quarter- and half-mile furrow systems (see Table 31, p. 19).

BORDER STRIP SYSTEMS

Border strip irrigation is used extensively on hay and grain crops and on trees and vines in the San Joaquin Valley. The irrigation system generally consists of a head ditch or pipeline to deliver water to the field and a series of borders or ridges that guide a moving sheet of water down strips, typically 20 to 60 feet wide.

For the low level of management, the system configuration consists of half-mile runs. Quarter-mile runs are used for the medium and high management levels.

For low levels of management, it is assumed that the water delivery system will consist of an unlined head ditch and large-diameter siphon tubes. For medium and high levels of management, it is assumed that the delivery system will consist of a buried plastic pipeline with alfalfa valves.

It is assumed that these systems can be used with the tailwater recovery system described in Table 31, p. 19.

SURGE CONTROL FURROW SYSTEMS

Surge control consists of intermittent delivery, or cycling, of water flow into furrows, compared to continuous flow for the full irrigation time used in standard furrow irrigation. The effect of surging is that the advance time, or the time required for flows to reach the end of the furrows, is reduced. The result is a smaller difference between infiltration opportunity times at the head and tail ends of the furrows and, consequently, more uniform application of water compared to standard furrows.

Surge flow cycling can be achieved by manual operation of control valves, gates, or siphon tubes; however, automated control using a prefabricated surge valve appears to be the most practical means of control. Because surge control furrows represent an advanced technology, it is assumed for all management levels that automated control and return flow systems would be incorporated.

The half-mile surge control system includes a quarter-mile of carry pipe that conveys the water to the center of the head of the field and a surge valve that alternates the flow of water to the two quarter-mile sections of gated pipe that run across the head of the field. The surge valve assumed is a generic representation of a few model types currently available on the market. The valve uses either batteries or a small solar collector to power a microprocessor and the butterfly actuator. The microprocessor can be programmed to alternate the flow according to different schedules.

The quarter-mile surge control system uses the surge valve near the irrigation turnout to alternate the flow between the upper and lower ends of the field. This layout requires a quarter-mile of carry pipe along the side of the field and two half-mile lengths of gated pipe along the head and center of the field.

HANDMOVE SPRINKLER SYSTEMS

Handmove sprinklers are commonly used throughout the San Joaquin Valley on cotton, alfalfa, row crops, small grains and other crops. The system used to represent handmove sprinklers is a typical quarter-section layout. The layout incorporates a booster pump near the irrigation turnout, an aluminum above-ground mainline that runs along half the length of one side and across the center of the square field, and portable aluminum sprinkler laterals.

With a total lateral length of 1/4 mile, 4-inch-diameter laterals are required to obtain satisfactory pressure uniformity by avoiding high friction loss. The sprinkler spacing used is 50 feet along the mainline and 30 feet along the lateral. There are six laterals on each side of the mainline at any one time.

The sprinklers and risers assumed are those typically used on cotton installations. The booster pump used in the system has a discharge flow rate of 1,600 gallons per minute (gpm) at 80 pounds per square inch (psi) pressure at the pump discharge. Low pressure sprinkler nozzles were not included for any management level because use of these devices has not shown a net economic advantage (Gohring and Wallender, 1987).

SURFACE DRIP SYSTEMS

For surface drip irrigation methods, a single irrigation system was chosen to represent the three levels of management, because drip systems are often installed as turnkey systems.

The characteristic surface drip system consists of a booster pump, filtration station, buried mainline and submains, and lateral distribution lines. The booster pump near the irrigation turnout is designed to deliver 1,000 gpm at 60 psi pressure at the pump discharge. The filtration system consists of a sand media filter and screen filters. The buried PVC mainline is installed across one end of the field and supplies four separate buried PVC submains that run the length of the field. The above-ground polyethylene drip tube is assumed to be spaced at 18-foot intervals along the submain. The plug-in drip emitters are assumed to be installed approximately every 21 feet along the laterals.

LINEAR MOVE SPRINKLER SYSTEMS

A linear move sprinkler system uses a traveling pipeline that is suspended approximately 10 feet above ground on small motorized tractor units. The water is distributed to the field by sprinklers, typically mounted on spray booms, attached to the elevated pipe. The traveling pipeline is typically fed by a traveling pump station that draws water from an open ditch.

Linear moves are used on a limited basis in some areas of the San Joaquin Valley. Proper system operation is critical to successful adaptation. If travel speeds are too slow, the moisture deficiency of crops may become too great between irrigations. Slow travel speeds on certain soils can also cause the small tractor units to become stuck. When travel speeds are too fast, the crops may receive more damage from saline water and energy costs will increase.

Apparently because of the complexities in operating and maintaining linear moves and the high initial capital cost, this technology has not been widely adapted to the San Joaquin Valley.

The representative linear move system consists of a 1-mile-long concrete-lined supply ditch and typical half-mile-long, center-fed linear move system.

TAILWATER RECOVERY SYSTEM

The tailwater recovery system is used to carry runoff water to the head of the field to be reapplied. The system components include a sump, pumping plant, and return pipeline.

For this study, it is assumed that the return pipeline is 1/2-mile long so that runoff can be reapplied to any part of the field.

PERFORMANCE CHARACTERIZATIONS

To facilitate hydrologic modeling, each of the 11 previously described irrigation systems is characterized with respect to its hydraulic performance. These characterizations consist of fractions that specify the distribution of applied water to each of the following four uses and losses.

- Beneficial Use (BU) - consists primarily of crop evapotranspiration
- Deep Percolation Loss (DP) - consists of water percolating below the root zone
- Uncollected Runoff Loss (UR) - consists of tailwater that is not collected for reuse
- Evaporation Loss (EL) - consists of evaporation from head and tail ditches and from droplets as they travel through the air from sprinkler nozzles to the ground surface

The four distribution fractures always total to exactly one to account for all applied water. Each of the 11 systems is characterized with respect to three management levels, resulting in a total of 33 characterizations (Table 2).

Irrigation system performance evaluations conducted in Westlands Water District during the 1987-88 irrigation season (October 1987 through September 1988) are the principal basis for the characterizations (SJVDP, 1988). That survey included evaluation of one preseason and at least one growing season irrigation event on more than 200 individual fields, facilitating a seasonal representation of irrigation application efficiency. To be consistent with the Westlands survey, the characterizations presented here also represent seasonal performance or application efficiencies.

Relative to other parts of the San Joaquin Valley, the Westlands data were considered to represent an average or medium level of irrigation management. The Westlands data, in combination with other information sources, were adjusted to represent the low and high management levels previously described. The high management level is intended to represent the best seasonal application efficiency potentially achievable with each system.

FURROW SYSTEMS

For all four furrow categories, the distribution fractions used for medium and high management furrows are based on those presented by the SJVDP (1988) for average and good management levels.

Table 2
DISTRIBUTION FRACTIONS

IRRIG. TECH.	MGMT. LEVEL	BU (%)	DP (%)	UR (%)	EL (%)
F2	LOW	45	39	15	1
	MED	64	32	3	1
	HIGH	70	26	3	1
F2-R	LOW	52	46	1	1
	MED	71	28	0	1
	HIGH	76	23	0	1
F4	LOW	49	32	18	1
	MED	67	29	3	1
	HIGH	72	24	3	1
F4-R	LOW	58	38	3	1
	MED	74	23	2	1
	HIGH	82	17	0	1
BORD	LOW	45	39	15	1
	MED	66	30	3	1
	HIGH	80	16	3	1
BORD-R	LOW	56	40	3	1
	MED	73	24	2	1
	HIGH	85	14	0	1
SURG-2	LOW	58	40	1	1
	MED	74	24	1	1
	HIGH	79	19	1	1
SURG-4	LOW	62	34	3	1
	MED	78	19	2	1
	HIGH	87	12	0	1
HMS	LOW	51	35	5	9
	MED	66	27	1	6
	HIGH	77	18	1	4
DRIP	LOW	62	38	0	0
	MED	74	26	0	0
	HIGH	90	10	0	0
LINEAR	LOW	63	20	8	9
	MED	80	13	1	6
	HIGH	86	10	0	4

For half-mile furrows under medium management, the BU fraction is 3 percent less and the DP fraction is 3 percent more than the values presented by the SJVDP (1988) to create a greater relative difference between the half- and quarter-mile furrows. For the quarter-mile furrows, the values used for medium and high management levels are those presented by the SJVDP (1988).

The low management distribution fractions were obtained by considering the effects of management on deep percolation and uncollected runoff fractions.

It is assumed that low management practices will increase deep percolation 20 to 25 percent. The increase in the DP fraction is assumed to be greater for the half-mile furrows since differences in intake opportunity times will be greater.

The uncollected runoff fraction is assumed to increase a small amount for furrows with tailwater recovery systems. For systems without return flow systems, the increase in UR is assumed to be between 10 and 15 percent. The increase is assumed to be slightly greater for the quarter-mile furrows since runoff amounts have a potential for being higher with shorter advance distances.

For all surface systems, the evaporation losses are assumed to remain at 1 percent regardless of management level.

BORDER STRIP SYSTEMS

Border strip irrigation is similar to furrow irrigation in that water is delivered to the upstream end of the field and the soil surface is used to convey the water across the field. For this reason, the uncollected runoff and evaporation losses for border strip are assumed to be the same as for furrows.

Borders have a slightly higher potential for deep percolation because water must travel transversely across the field as well as laterally. This added flow dimension will increase the difference in intake opportunity time, which influences deep percolation. It is assumed that DP will be 1 to 3 percent higher for border strips than for furrows. This increase will be greater for low management than for medium and high management levels.

SURGE CONTROL FURROW SYSTEMS

Because surge flow is a technique of irrigating furrows, it is assumed that the benefits of surge will not be effectively realized for low management. Therefore the distribution fractions for surge flow under low management are assumed to be only slightly better than for standard furrows. For the

half- and quarter-mile surge control systems, it is assumed that deep percolation will be 1 percent less than their standard furrow counterparts.

Under medium and high management, it is assumed that the evaporation loss and uncollected runoff of surge flow systems will be the same as those for standard furrows. This assumption is based on studies showing that surge flow can reduce differences in intake opportunity time.

Growers in the San Joaquin Valley have indicated that surge flow irrigation yields significant benefits (Taylor, 1987; Wooley, 1987). These benefits include a reduction in differences in intake opportunity time between upstream and downstream ends of the field, a decrease in water use, and a decrease in total advance time.

Charles Burt (1988) has estimated that the maximum potential BU of surge control irrigation is approximately 85 percent, and that BU of 80 percent is currently being achieved by some growers in the San Joaquin Valley.

A BU fraction of 87 percent is assumed for quarter-mile surge systems operated under a high level of management. A similar relationship is assumed to exist between the BU fractions for surge flow systems and those of conventional furrows: BU is approximately 4 percent lower for half-mile furrows than for quarter-mile furrows under the same level of management, and BU under medium management level is approximately 5 to 7 percent lower than for high management.

HANDMOVE SPRINKLER SYSTEMS

The distribution fractions for handmove sprinklers under medium management are assumed to be those given by the SJVDP (1988) for average management. For high management, it was assumed that the use of alternate sets and proper system pressures would result in a BU fraction of 77 percent, slightly higher than that reported by the SJVDP (1988). For low management, it is assumed that deep percolation increases approximately 8 percent. It is assumed that as management level decreases, the runoff will increase significantly. This consequence is likely to occur when set times are too long, adequate pressures are not maintained, too many laterals are operated at once, or leaking pipes or poorly operating sprinklers are not repaired or replaced.

The UR fraction is assumed to be approximately 4 percent higher for low management levels than for medium levels. Jensen (1984) has reported that evaporation losses are seldom higher than 9 percent of the applied water for sprinkler irrigation systems.

The resulting BU fraction for low management is approximately 15 percent lower than for high management levels.

SURFACE DRIP SYSTEMS

Runoff and evaporation losses for drip systems are usually negligible. For this reason, the UR and EL fractions for all management levels are assumed to be zero.

The BU fractions reported for drip irrigation by the SJVDP (1988) were adjusted upward by 4 to 6 percentage points to reflect the benefit of potentially high application uniformities associated with the method.

If not properly managed, drip emitters can become clogged, which drastically decreases uniformity. Nakayama and Bucks (1979) have reported that having 20 percent of the emitters plugged can result in an application uniformity of approximately 50 percent. However, considering recent advances in filtration technology and clogging prevention, the BU fraction under low management was reduced to only 62 percent.

LINEAR MOVE SPRINKLER SYSTEMS

Linear move sprinkler systems, when operated correctly, have a high potential for uniform water application (USDA-SCS, 1983). The SJVDP (1988) has indicated that linear move systems can obtain beneficial use fractions of 75 to 85 percent.

Runoff and evaporation losses of linear moves are assumed to be similar to those of handmove sprinklers because both irrigation methods use aerial spraying for applying water to the field. However, the UR fraction was increased from 5 to 8 percent under the low management level to reflect the relatively high runoff that can result from high application rates typical of linear move systems.

Under low management, the BU fraction was estimated to be 63 percent to reflect the relatively high distribution uniformities typical of moving lateral systems, compared to stationary systems such as handmove sprinklers.

For medium management, the BU fraction is assumed to be the average of those reported by the SJVDP (1988). The BU of linear moves was described as being 75 to 85 percent; thus the BU fraction is assumed to be 80 percent for the medium management level.

For the high management level, the BU is assumed to be 86 percent. This is based on information gathered by Burt (1988) in which he noted that linear systems often are operated at 85 percent efficiency and can be operated at 90 percent.

SYSTEM COSTS

Costs of purchase and operation were prepared for each system. The following sections describe the costs for capital investment, system maintenance, pumping, labor, and management. Because some of the cost components depend on the amount of water applied, and therefore the crop grown, costs were developed with respect to seven of the most common crops. However, some combinations of systems and crops are excluded due to incompatibility between irrigation operations and cultural activities.

CAPITAL COSTS

Costs of purchasing and installing the irrigation systems described above were computed by compiling costs from various sources. To obtain system component costs, irrigation retailers were asked for realistic price data for the components when purchased in quantities required for the systems. Data sources are listed in Appendix B.

Annual costs were determined by amortizing each component over its estimated useful life (Tables 3a through 31). A 10 percent interest rate was used for all calculations. To validate the range of costs, data sources were asked about rules of thumb for costs of different systems. Many sources had general impressions about the cost per acre of the given systems. These general costs were compared to the total initial investment costs that were calculated for the systems.

MAINTENANCE COSTS

Maintenance costs are required to keep the irrigation equipment in working condition. The management level will significantly affect the maintenance cost. Maintenance cost can be estimated as a percentage of the total capital cost of the irrigation system (Jensen, 1984).

Surface Systems

Maintenance costs for surface systems are divided into three categories: delivery, land grading, and return system. The maintenance costs for the delivery system are based on the percentages of the capital costs of the components. The land grading is assumed constant for a particular size field and management level. The maintenance costs of the return system are similar to those for the water delivery system.

Water Delivery Maintenance. For low management furrows and border strip, the water delivery system consists of the unlined head ditch and the siphon tubes. The capital cost of this system reflects an annual reinstallation of the head

Table 3a

COMPONENT COSTS FOR 1/2 MILE FURROWS (LOW MANAGEMENT)

I = 10%

ITEM	UNIT COSTS							SUB-TOTAL COSTS	ANNUAL COSTS (@ I%)
	QTY	UNIT	LIFE (years)	INFORMATION SOURCES					
				No. 2	No. 9	No. 16	ESTIMATE		
* Head Ditch	2640	ft./yr.	1	--	--	$0.10	$0.10	$1,622	$264
1-1/2 In. Siphon Tubes	110	ea.	5	$3.00	$3.50	--	$3.50	$385	$102
					Total			$2,007	$366
					Initial Invest ($/acre) =			$13	
					Unit Cost ($/acre/yr) =				$2.28

COMPARISON OF SYSTEM COSTS

	Source No. 16	Calculated Estimate
Initial System Cost ($/acre)	$12	$13

* Cost shown is annual cost of installing head ditch. Sub-total cost is present value of installation cost over 10-year period.

Table 3b

COMPONENT COSTS FOR 1/2 MILE FURROWS (MEDIUM AND HIGH MANAGEMENT)

I = 10%

ITEM	UNIT COSTS							SUB-TOTAL COSTS	ANNUAL COSTS (@ I%)
	QTY	UNIT	LIFE (years)	INFORMATION SOURCES					
				No. 1	No. 2	No. 9	ESTIMATE		
10-In. Gated Pipe	2640	ft.	8	$6.04	$5.29	$5.90	$6.00	$15,840	$2,969
					Total			$15,840	$2,969
					Initial Invest ($/acre) =			$99	
					Unit Cost ($/acre/yr) =				$19

COMPARISON OF SYSTEM COSTS

	Information Source		Calculated
	No. 15	No. 16	Estimate
Initial System Cost ($/acre)	$90	$119	$99

Table 3c

COMPONENT COSTS FOR 1/4 MILE FURROWS (LOW MANAGEMENT)

I = 10%

ITEM	UNIT COSTS							SUB-TOTAL COSTS	ANNUAL COSTS (@ I%)
	QTY	UNIT	LIFE (years)	INFORMATION SOURCES					
				No. 2	No. 9	No. 16	ESTIMATE		
* Head Ditch	6600	ft./yr.	1	--	--	$0.10	$0.10	$4,055	$660
1-1/2 In. Siphon Tubes	220	ea.	5	$3.00	$3.50	--	$3.50	$770	$203
					Total			$4,825	$863
					Initial Invest ($/acre) =			$30	
					Unit Cost ($/acre/yr) =				$5.39

COMPARISON OF SYSTEM COSTS

	Source No. 16	Calculated Estimate
Initial System Cost ($/acre)	$58	$30

* Cost shown is annual cost of installing head ditch. installation cost over 10-year period.

Table 3d

COMPONENT COSTS FOR 1/4 MILE FURROWS (MEDIUM AND HIGH MANAGEMENT)

I = 10%

ITEM	UNIT COSTS								SUB-TOTAL COSTS	ANNUAL COSTS (@ I%)
	QTY	UNIT	LIFE (years)	INFORMATION SOURCES						
				No. 1	No. 2	No. 9	ESTIMATE			
10-In. Gated Pipe	5280	ft.	8	$6.04	$5.29	$5.90	$6.00		$31,680	$5,938
10-In. Plain Pipe	1320	ft.	8	$5.40	$5.14	--	$5.25		$6,930	$1,299
Misc. Fittings	1	ea.	8	$400	--	$450	$450		$450	$84
10-In. Butterfly Valves	2	ea.	10	$239	--	$225	$235		$470	$76
									$39,530	$7,398
					Initial Invest ($/acre) =				$247	
					Unit Cost ($/acre/yr) =					$46

COMPARISON OF SYSTEM COSTS

	Information Source No. 15	Information Source No. 16	Calculated Estimate
Initial System Cost ($/acre)	$200	$181	$247

Table 3e

COMPONENT COSTS FOR 1/2 MILE BORDER STRIP (LOW MANAGEMENT)

i = 10%

ITEM	UNIT COSTS					SUB-TOTAL COSTS	ANNUAL COSTS (@ I%)
	QTY	UNIT	LIFE (years)	INFO. SOURCES			
				No. 16	ESTIMATE		
* Head Ditch	2640	ft./yr.	1	$0.10	$0.10	$1,622	$264
1-1/2 In. Siphon Tubes	22	ea.	5	$30.00	$30.00	$660	$174
			Total			$2,282	$438
			Initial Invest ($/acre) =			$14	
			Unit Cost ($/acre/yr) =				$2.74

* Cost shown is annual cost of installing head ditch. Sub-total cost is present value of installation cost over 10-year period.

Table 3f

COMPONENT COSTS FOR 1/4 MILE BORDER STRIP (MEDIUM AND HIGH MANAGEMENT)

I = 10%

ITEM	UNIT COSTS								SUB-TOTAL COSTS	ANNUAL COSTS (@ I%)
	QTY	UNIT	LIFE (years)	INFORMATION SOURCES						
				No. 1	No. 2	No. 6	No. 9	ESTIMATE		
15-In. Low Head PVC Pipe	6600	ft.	10	$3.98	$3.90	--	$4.00	$4.00	$26,400	$4,296
12-In. Alfalfa Valves w/ Riser & Saddles	130	ea.	10	$90	$95	$108	$92	$92	$11,960	$1,946
Misc. Fittings & Vents	1	ea.	10	$700	--	--	$600	$650	$650	$106
15-in. Butterfly Valves	2	ea.	10	$457	--	--	$450	$455	$910	$148
PIPE INSTALLATION:										
15-In. Pipe Installation	6600	ft.	10	--	$1.45	--	$1.50	$1.50	$9,900	$1,611
						Total			$49,820	$8,108
						Initial Invest ($/acre) =			$311	
						Unit Cost ($/acre/yr) =				$51

COMPARISON OF SYSTEM COSTS

	Source		Calculated
	No. 15	No. 16	Estimate
Initial System Cost ($/acre)	$320	$185	$311

Table 3g

COMPONENT COSTS FOR 1/2 MILE SURGE CONTROLLED FURROWS

i = 10%

ITEM	QTY	UNIT	LIFE (years)	UNIT COSTS: INFORMATION SOURCES No. 1	No. 2	No. 9	No. 10	ESTIMATE	SUB-TOTAL COSTS	ANNUAL COSTS (@ i%)
10-In. Gated Pipe	2640	ft.	8	$6.04	$5.29	$5.90	--	$6.00	$15,840	$2,969
10-in. Plain Pipe	1320	ft.	8	$5.40	$5.14	--	--	$5.25	$6,930	$1,299
Misc. Fittings	1	ea.	8	$400	--	$450	--	$450	$450	$84
10-in. Surge Valve	1	ea.	8	--	--	$1,250	$1,200	$1,250	$1,250	$234
						Total			$24,470	$4,587
						Initial Invest ($/acre) =			$153	
						Unit Cost ($/acre/yr) =				$29

COMPARISON OF SYSTEM COSTS

	Source No. 16	Calculated Estimate
Initial System Cost ($/acre)	$111	$153

Table 3h

COMPONENT COSTS FOR 1/4 MILE SURGE CONTROLLED FURROWS

i = 10%

ITEM	QTY	UNIT	LIFE (years)	UNIT COSTS: INFORMATION SOURCES No. 1	No. 2	No. 9	No. 10	ESTIMATE	SUB-TOTAL COSTS	ANNUAL COSTS (@ i%)
10-In. Gated Pipe	5280	ft.	8	$6.04	$5.29	$5.90	--	$6.00	$31,680	$5,938
10-in. Plain Pipe	1320	ft.	8	$5.40	$5.14	--	--	$5.25	$6,930	$1,299
Misc. Fittings	2	ea.	8	$400	--	$450	--	$450	$900	$169
10-in. Butterfly Valve	2	ea.	10	$239	--	$225	--	$235	$470	$76
10-in. Surge Valve	1	ea.	8	--	--	$1,250	$1,200	$1,250	$1,250	$234
						Total			$41,230	$7,717
						Initial Invest ($/acre) =			$258	
						Unit Cost ($/acre/yr) =				$48

COMPARISON OF SYSTEM COSTS

Information Source	Source No. 16	Calculated Estimate
Initial System Cost ($/acre)	$159	$258

Table 3I

COMPONENT COSTS FOR SPRINKLER SYSTEMS

HANDMOVE SPRINKLERS

Pump Q = 1600 gpm

Pump H = 80 psi

i = 10%

ITEM	QTY	UNIT	LIFE (years)	UNIT COSTS — INFORMATION SOURCES: No. 9	No. 11	No. 13	No. 18	No. 19	ESTIMATE	SUB-TOTAL COSTS	ANNUAL COSTS (@ i%)
12-in. Al. M.L. w/ Valve	13	ea.	10	$163	--	--	$145	--	$160	$2,080	$339
12-in. Al. M.L. w/o Valve	66	ea.	10	$140	--	--	$120	--	$135	$8,910	$1,450
10-in. Al. M.L. w/ Valve	18	ea.	10	$159	$156	--	$125	--	$150	$2,700	$439
10-in. Al. M.L. w/o Valve	18	ea.	10	$124	--	--	$100	--	$120	$2,160	$352
8-in. Al. M.L. w/ Valve	9	ea.	10	$124	$125	--	$105	--	$120	$1,080	$176
8-in. Al. M.L. w/o Valve	9	ea.	10	$96	--	--	$80	--	$90	$810	$132
6-in. Al. M.L. w/ Valve	13	ea.	10	$94	--	--	$85	--	$90	$1,170	$190
6-in. Al. M.L. w/o Valve	13	ea.	10	$67	--	--	$60	--	$65	$845	$138
4-in. by 30-ft. Al. Lat.	530	ea.	8	$51	$53	--	--	--	$52	$27,560	$5,166
R.B. 29JH w/ Nozzle	530	ea.	4	$1.75	--	--	$2.13	--	$2.00	$1,060	$334
12-in. riser	530	ea.	8	$5.65	--	--	$6.14	--	$6.00	$3,180	$596
Valve Opening Elbows	12	ea.	8	$45	$44	--	--	--	$45	$540	$101
100 H.P. Pump Purchase	1	ea.	20	--	--	$7,253	$22,000	--	$15,000	$15,000	$1,762
100 H.P. Pump Rent (for comp.)	1	ea.	--	$1,350	--	--	--	$1,500	$1,450	--	--
							Total			$67,095	$11,175
							Initial Invest ($/acre) =			$419	
							Unit Cost ($/acre/yr) =				$70

COMPARISON OF SYSTEM COSTS

	Source: No. 15	Source: No. 16	Calculated Estimate
Initial System Cost ($/acre)	$394	$357	$419

Table 3j
COMPONENT COSTS FOR SURFACE DRIP

Pump Q = 1000 gpm
Pump H = 60 psi
i = 10%

ITEM	QTY	UNIT	LIFE (years)	UNIT COSTS — INFORMATION SOURCES No. 1	No. 8	No. 9	No. 10	No. 13	No. 14	No. 15	No. 18	ESTIMATE	SUB-TOTAL COSTS	ANNUAL COSTS (@ i%)
Sand Media Filter	1	ea.	20	--	--	--	$9,200	--	$9,000	--	--	$9,000	$9,000	$1,057
Screen Filter	1	ea.	20	--	--	--	$4,100	--	$11,000	--	--	$11,000	$11,000	$1,292
10-in. Class 125 PVC Pipe	990	ft.	15	$6.11	$6.10	--	$6.05	--	$5.95	--	--	$6.00	$5,940	$781
8-in. Class 125 PVC Pipe	660	ft.	15	$3.93	$3.67	$3.44	$3.20	--	$3.20	--	--	$3.30	$2,178	$286
6-in. Class 125 PVC Pipe	4100	ft.	15	$2.32	$2.17	$2.04	$1.89	--	$1.89	--	--	$2.00	$8,200	$1,078
4-in. Class 125 PVC Pipe	3000	ft.	15	$1.07	$0.96	$0.94	$0.87	--	$1.67	--	--	$1.00	$3,000	$394
3-in. Class 125 PVC Pipe	2000	ft.	15	$0.65	$0.61	$0.57	$0.53	--	$0.53	--	--	$0.55	$1,100	$145
2-in. Class 125 PVC Pipe	1600	ft.	15	$0.31	$0.28	$0.26	$0.24	--	$0.25	--	--	$0.25	$400	$53
1-in. Class 125 PVC Pipe	1000	ft.	15	$0.120	--	--	$0.096	--	$0.100	--	--	$0.100	$100	$13
0.5-in. P.E. Drip Tubing	400,000	ft.	10	$0.039	--	$0.035	$0.030	--	$0.040	--	--	$0.040	$16,000	$2,604
1 GPH Emitter	60,000	ea.	3	$0.15	--	$0.20	--	--	$0.20	--	--	$0.20	$12,000	$4,825
50 H.P. Pump Purchase	1	ea.	20	--	--	--	--	$7,015	--	--	$14,500	$12,000	$12,000	$1,410
PIPE INSTALLATION:														
10-in. Installation	990	ft.	15	--	--	--	$0.60	--	$0.90	$1.10	--	$0.95	$941	$124
8-in. Installation	660	ft.	15	--	--	--	$0.60	--	$0.85	$1.10	--	$0.95	$627	$82
6-in. Installation	4100	ft.	15	--	--	--	$0.60	--	$0.80	$1.10	--	$0.95	$3,895	$512
4-in. Installation	3000	ft.	15	--	--	--	$0.47	--	$0.75	$0.84	--	$0.60	$1,800	$237
3-in. Installation	2000	ft.	15	--	--	--	$0.47	--	$0.60	$0.57	--	$0.60	$1,200	$158
2-in. Installation	1600	ft.	15	--	--	--	$0.47	--	$0.55	$0.57	--	$0.60	$960	$126
1-in. Installation	1000	ft.	15	--	--	--	$0.47	--	$0.40	$0.57	--	$0.60	$600	$79
0.5-in. Installation	400,000	ft.	10	$0.10	--	--	--	--	--	--	--	$0.30	$120,000	$19,529
Emitter Installation	60,000	ea.	3	$0.10	--	--	--	--	--	--	--	$0.20	$12,000	$4,825
												Total	$222,941	$39,611
												Initial Invest ($/acre) =	$1,393	
												Unit Cost ($/acre/yr) =		$248

COMPARISON OF SYSTEM COSTS

	Information Source No. 5	No. 9	No. 15	No. 18	Calculated Estimate
Initial System Cost ($/acre)	$1,000	$1,300	$1,000	$1,250	$1,393

Table 3k
COMPONENT COSTS FOR LINEAR MOVE SPRINKLERS

i = 10%

ITEM	UNIT COSTS							SUB-TOTAL COSTS	ANNUAL COSTS (@ I%)
	QTY	UNIT	LIFE (years)	INFORMATION SOURCES					
				No. 3	No. 4	No. 7	ESTIMATE		
Complete Linear Move System	1	ea.	10	135,000	160,000	160,000	170,000	170,000	$27,667
Concrete-lined Ditch	5280	ft.	10				6.00	31,680	$5,156
					Total			201,680	32,822
					Initial Invest ($/acre) =			$630	
					Unit Cost ($/acre/yr) =				$103

Table 3l
COMPONENT COSTS FOR TAILWATER RECOVERY SYSTEM

i = 10%

ITEM	UNIT COSTS							SUB-TOTAL COSTS	ANNUAL COSTS (@ I%)
	QTY	UNIT	LIFE (years)	INFORMATION SOURCES					
				No. 11	No. 16	No. 17	ESTIMATE		
Sump Excavation	1	ea.	15	$1,000	$4,800	--	--	--	--
Pump, Stand, & Appurtanances	1	ea.	15	$3,800	$11,500	--	--	--	--
Return Line	1	ea.	15	$7,200	$15,000	--	--	--	--
Total			15	$12,000	$31,300	$28,000	$30,000	$30,000	$3,944
					Initial Invest ($/acre) =			$188	
					Unit Cost ($/acre/yr) =				$25

ditch. It is assumed that the maintenance cost for this water delivery system will be limited to the replacement of approximately 7 percent of the siphon tubes each year.

For the medium and high management level furrow systems, the water delivery maintenance cost is assumed to be 1.5 and 2.5 percent, respectively, of the capital cost of the gated pipe (Jensen, 1984).

For the border strip system, the water delivery maintenance costs for medium and high management levels are 0.5 and 0.75 percent, respectively, of the cost of the delivery system, because the pipeline is buried (Jensen, 1984).

The water delivery maintenance costs for surge flow systems are equal to the maintenance cost of the gated pipe and the surge valve. The maintenance cost of the gated pipe is equal to 1.0, 1.5, and 2.5 percent of the pipe cost for low, medium, and high management levels, respectively; and the maintenance cost is assumed to be 2.5 percent of the valve cost for all levels of management.

Land Grading. Land grading or smoothing is required periodically for surface irrigation systems because farming and irrigation practices tend to redistribute the soil in a way that disturbs the irrigation grade. Land grading is accomplished with a minimum of cuts and fills and reestablishes the desired grades on the field.

The cost of land grading was estimated using the following assumptions:

- The field is covered once by the tractor-scraper.
- The effective width of the scraper is 8 feet (including overlap).
- The average tractor speed is 5 miles per hour.
- The cost of grading is $20 per hour.
- An equivalent length of 60 feet is added to the field to account for turnaround at the ends of the field.

An effective width of 8 feet over a 2,640-foot-wide field results in 330 passes with the scraper. The effective length of the field is 2,700 feet (2,640 feet plus the 60-foot equivalent length). Dimensional analysis shows that 330 passes at 2,700 feet for each pass at an average speed of 5 miles per hour results in approximately 33 hours to complete land grading.

At $20 per hour, the cost of land grading for each time the field is graded is approximately $4.10/acre for a quarter-section field.

To determine the annual cost of land grading for the three management levels, it is assumed that for low management the field will be graded every 8 years, for medium management every 4 years, and for high management every 2 years. This results in the following grading costs:

- Low Management - $0.50/acre/year
- Medium Management - $1.00/acre/year
- High Management - $2.00/acre/year

Return System Maintenance. The maintenance costs for the tailwater return system are calculated in the same manner as maintenance costs for the water delivery system. The capital cost percentages assumed for the return system are given in Table 4 (Jensen, 1984).

Maintenance costs for the recovery system are $1.20, $2.70, and $4.20 per acre per year for low, medium, and high management levels, respectively.

Pressurized Systems

The maintenance costs for the handmove sprinklers, surface drip, and linear move sprinklers are based on percentages of the capital costs of individual components. These percentages are presented in Table 5 (Jensen, 1984).

The capital and maintenance costs for each system are summarized in Table 6.

CONSUMPTIVE USE

The following seven crop types were chosen to represent the most common agricultural settings in the southern San Joaquin Valley:

- ALF - Alfalfa and other hay crops
- TFN - Trees and vines
- ROW - Row crops (primarily cotton)
- GRN - Grains
- VEG - Vegetable crops
- GRAS - Grasslands areas
- POND - Wetlands areas

Average annual consumptive use of each crop category was estimated from DWR 133-4 (Table 7). The consumptive use of the GRAS category is based on typical grain crops. Water use by POND was estimated by the average evapotranspiration (ET) of rice.

Table 4
PERCENT OF CAPITAL COST USED FOR MAINTENANCE CALCULATION IN TAILWATER RETURN SYSTEMS

Component	Low Mgmt.	Medium Mgmt.	High Mgmt.
Sump	1	1.5	2
Pump	1	2.5	4
Pipe	0.25	0.5	0.75

Table 5
MAINTENANCE COST AS A PERCENT OF CAPITAL COST*

System Component	Percent of Capital Costs		
	Low Mgmt.	Medium Mgmt.	High Mgmt.
Hand-move Sprinklers			
Aluminum Pipe	1.50	2.00	2.50
Sprinklers	5.90	6.50	8.00
Pump	1.00	2.50	4.00
Surface Drip			
Buried Pipe	0.25	0.50	0.75
Drip Tubing	1.50	2.00	2.50
Emitters	4.00	7.00	10.00
Filters	6.00	7.50	9.00
Pump	1.00	2.50	4.00
Linear-move Sprinklers			
Linear-move	5.00	6.50	8.00
Canals	1.00	1.50	2.00

* Estimated from Jensen (1984).

Table 6
ANNUAL CAPITAL AND MAINTENANCE COSTS
FOR IRRIGATION METHODS AND MANAGEMENT LEVELS

IRRIG. METHOD	MGMT. LEVEL	CAPITAL COST			MAINTENANCE COST				COMBINED TOTAL
		DELIVERY SYSTEM	RETURN SYSTEM	TOTAL	DELIVERY SYSTEM	LAND GRADING	RETURN SYSTEM	TOTAL	
F2	LOW	2.28	0.00	2.28	0.10	0.50	0.00	0.60	2.88
	MED	18.56	0.00	18.56	1.50	1.00	0.00	2.50	21.06
	HIGH	18.56	0.00	18.56	2.50	2.00	0.00	4.50	23.06
F2-R	LOW	2.28	24.65	26.94	0.10	0.50	1.20	1.80	28.74
	MED	18.56	24.65	43.21	1.50	1.00	2.70	5.20	48.41
	HIGH	18.56	24.65	43.21	2.50	2.00	4.20	8.70	51.91
F4	LOW	5.39	0.00	5.39	0.10	0.50	0.00	0.60	5.99
	MED	46.24	0.00	46.24	3.70	1.00	0.00	4.70	50.94
	HIGH	46.24	0.00	46.24	6.20	2.00	0.00	8.20	54.44
F4-R	LOW	5.39	24.65	30.05	0.10	0.50	1.20	1.80	31.85
	MED	46.24	24.65	70.89	3.70	1.00	2.70	7.40	78.29
	HIGH	46.24	24.65	70.89	6.20	2.00	4.20	12.40	83.29
BORD	LOW	2.74	0.00	2.74	0.10	0.50	0.00	0.60	3.34
	MED	50.67	0.00	50.67	1.60	1.00	0.00	2.60	53.27
	HIGH	50.67	0.00	50.67	2.30	2.00	0.00	4.30	54.97
BORD-R	LOW	2.74	24.65	27.39	0.10	0.50	1.20	1.80	29.19
	MED	50.67	24.65	75.33	1.60	1.00	2.70	5.30	80.63
	HIGH	50.67	24.65	75.33	2.30	2.00	4.20	8.50	83.83
SURG-2	LOW	28.67	24.65	53.32	1.40	0.50	1.20	3.10	56.42
	MED	28.67	24.65	53.32	2.20	1.00	2.70	5.90	59.22
	HIGH	28.67	24.65	53.32	3.60	2.00	4.20	9.80	63.12
SURG-4	LOW	48.23	24.65	72.88	2.70	0.50	1.20	4.40	77.28
	MED	48.23	24.65	72.88	3.90	1.00	2.70	7.60	80.48
	HIGH	48.23	24.65	72.88	6.40	2.00	4.20	12.60	85.48
HMS	LOW	69.84	0.00	69.84	6.80	0.00	0.00	6.80	76.64
	MED	69.84	0.00	69.84	10.20	0.00	0.00	10.20	80.04
	HIGH	69.84	0.00	69.84	14.20	0.00	0.00	14.20	84.04
DRIP	LOW	247.57	0.00	247.57	13.10	0.00	0.00	13.10	260.67
	MED	247.57	0.00	247.57	24.50	0.00	0.00	24.50	272.07
	HIGH	247.57	0.00	247.57	32.80	0.00	0.00	32.80	280.37
LINEAR	LOW	102.00	0.00	102.00	21.40	0.00	0.00	21.40	123.40
	MED	102.00	0.00	102.00	29.40	0.00	0.00	29.40	131.40
	HIGH	102.00	0.00	102.00	37.50	0.00	0.00	37.50	139.50

Table 7
CONSUMPTIVE USE (AF/ac/yr)

IRRIG. TECH.	MGMT. LEVEL	ALF	TFN	ROW	GRN	VEG	GRAS	POND
F2	LOW	---	2.71	2.08	---	1	---	---
	MED	---	2.71	2.08	---	1	---	---
	HIGH	---	2.71	2.08	---	1	---	---
F2-R	LOW	---	2.71	2.08	---	1	---	---
	MED	---	2.71	2.08	---	1	---	---
	HIGH	---	2.71	2.08	---	1	---	---
F4	LOW	---	2.71	2.08	---	1	---	---
	MED	---	2.71	2.08	---	1	---	---
	HIGH	---	2.71	2.08	---	1	---	---
F4-R	LOW	---	2.71	2.08	---	1	---	---
	MED	---	2.71	2.08	---	1	---	---
	HIGH	---	2.71	2.08	---	1	---	---
BORD	LOW	4.17	2.71	---	1.25	---	1.4	6.8
	MED	4.17	2.71	---	1.25	---	1.4	6.8
	HIGH	4.17	2.71	---	1.25	---	1.4	6.8
BORD-R	LOW	4.17	2.71	---	1.25	---	1.4	---
	MED	4.17	2.71	---	1.25	---	1.4	---
	HIGH	4.17	2.71	---	1.25	---	1.4	---
SURG-2	LOW	---	2.71	2.08	---	1	---	---
	MED	---	2.71	2.08	---	1	---	---
	HIGH	---	2.71	2.08	---	1	---	---
SURG-4	LOW	---	2.71	2.08	---	1	---	---
	MED	---	2.71	2.08	---	1	---	---
	HIGH	---	2.71	2.08	---	1	---	---
HMS	LOW	4.17	2.71	2.08	---	1	---	---
	MED	4.17	2.71	2.08	---	1	---	---
	HIGH	4.17	2.71	2.08	---	1	---	---
DRIP	LOW	---	2.71	---	---	---	---	---
	MED	---	2.71	---	---	---	---	---
	HIGH	---	2.71	---	---	---	---	---
LINEAR	LOW	4.17	---	2.08	1.25	1	---	---
	MED	4.17	---	2.08	1.25	1	---	---
	HIGH	4.17	---	2.08	1.25	1	---	---

The volume of applied water was calculated for each crop, irrigation method, and management level combination (Table 8).

PUMPING COSTS

Three of the irrigation methods studied require pressurization. The system components reflect the assumption that each pressurized system includes an appropriate booster pump. To equitably assign costs to all of the systems considered, the cost of operating the booster pumps for the pressurized systems must be included.

The cost of operating a pumping plant over a period of time is a function of the total volume of water pumped and the average net pressure increase supplied by the pump. Dimensional analysis shows that:

$$P = 1.02 * V * H * C / Eff$$

where:

P = annual power cost in dollars per year
V = total volume pumped in acre-feet/year
H = total net delivery pressure in feet of water
C = unit cost for energy, assumed to be $0.08/kW-hr
Eff = total pumping plant efficiency

Values for V, the total pumped volume, are equal to the annual applied water. Values for H, given in Table 9, reflect the assumptions made for irrigation system components. The value of 8 cents per kilowatt-hour for the cost of energy is based on average electricity rates for the San Joaquin Valley. The pumping plant efficiency, Eff, is assumed to be 0.70 and reflects the combined pump and motor efficiency.

LABOR COSTS

Labor costs were estimated by considering the amount of labor required to apply a given volume of water. For each irrigation method and management level, the number of man-hours required to complete a typical irrigation was estimated. The typical volume of water applied per irrigation was then approximated so that the unit time requirement could be calculated.

Unit Time Requirements

Unit time requirements were adjusted to reflect the difficulties that would typically be encountered for the array of crops, irrigation methods, and management levels.

Table 8
APPLIED WATER (AF/ac/yr)

IRRIG. TECH.	MGMT. LEVEL	ALF	TFN	ROW	GRN	VEG	GRAS	POND
F2	LOW	---	6.02	4.62	---	2.22	---	---
	MED	---	4.23	3.25	---	1.56	---	---
	HIGH	---	3.87	2.97	---	1.43	---	---
F2-R	LOW	---	5.21	4.00	---	1.92	---	---
	MED	---	3.82	2.93	---	1.41	---	---
	HIGH	---	3.57	2.74	---	1.32	---	---
F4	LOW	---	5.53	4.24	---	2.04	---	---
	MED	---	4.04	3.10	---	1.49	---	---
	HIGH	---	3.76	2.89	---	1.39	---	---
F4-R	LOW	---	4.67	3.59	---	1.72	---	---
	MED	---	3.66	2.81	---	1.35	---	---
	HIGH	---	3.43	2.63	---	1.27	---	---
BORD	LOW	9.27	6.02	---	2.78	---	3.11	15.11
	MED	6.32	4.11	---	1.89	---	2.12	10.30
	HIGH	5.21	3.39	---	1.56	---	1.75	8.50
BORD-R	LOW	7.45	4.84	---	2.23	---	2.50	---
	MED	5.71	3.71	---	1.71	---	1.92	---
	HIGH	4.91	3.19	---	1.47	---	1.65	---
SURG-2	LOW	---	4.67	3.59	---	1.72	---	---
	MED	---	3.66	2.81	---	1.35	---	---
	HIGH	---	3.43	2.63	---	1.27	---	---
SURG-4	LOW	---	4.11	3.15	---	1.52	---	---
	MED	---	3.47	2.67	---	1.28	---	---
	HIGH	---	3.11	2.39	---	1.15	---	---
HMS	LOW	8.18	5.31	4.08	---	1.96	---	---
	MED	6.32	4.11	3.15	---	1.52	---	---
	HIGH	5.42	3.52	2.70	---	1.30	---	---
DRIP	LOW	---	4.37	---	---	---	---	---
	MED	---	3.66	---	---	---	---	---
	HIGH	---	3.01	---	---	---	---	---
LINEAR	LOW	6.62	---	3.30	1.98	1.59	---	---
	MED	5.21	---	2.60	1.56	1.25	---	---
	HIGH	4.85	---	2.42	1.45	1.16	---	---

Table 9
PUMPING COST ($/ac/yr)

IRRIG. TECH.	MGMT. LEVEL	PRESSURE BOOST (net psi)	ALF	TFN	ROW	GRN	VEG	GRAS	POND
F2	LOW	0	---	0.00	0.00	---	0.00	---	---
	MED	0	---	0.00	0.00	---	0.00	---	---
	HIGH	0	---	0.00	0.00	---	0.00	---	---
F2-R	LOW	0	---	0.00	0.00	---	0.00	---	---
	MED	0	---	0.00	0.00	---	0.00	---	---
	HIGH	0	---	0.00	0.00	---	0.00	---	---
F4	LOW	0	---	0.00	0.00	---	0.00	---	---
	MED	0	---	0.00	0.00	---	0.00	---	---
	HIGH	0	---	0.00	0.00	---	0.00	---	---
F4-R	LOW	0	---	0.00	0.00	---	0.00	---	---
	MED	0	---	0.00	0.00	---	0.00	---	---
	HIGH	0	---	0.00	0.00	---	0.00	---	---
BORD	LOW	0	0.00	0.00	---	0.00	---	0.00	0.00
	MED	0	0.00	0.00	---	0.00	---	0.00	0.00
	HIGH	0	0.00	0.00	---	0.00	---	0.00	0.00
BORD-R	LOW	0	0.00	0.00	---	0.00	---	0.00	---
	MED	0	0.00	0.00	---	0.00	---	0.00	---
	HIGH	0	0.00	0.00	---	0.00	---	0.00	---
SURG-2	LOW	0	---	0.00	0.00	---	0.00	---	---
	MED	0	---	0.00	0.00	---	0.00	---	---
	HIGH	0	---	0.00	0.00	---	0.00	---	---
SURG-4	LOW	0	---	0.00	0.00	---	0.00	---	---
	MED	0	---	0.00	0.00	---	0.00	---	---
	HIGH	0	---	0.00	0.00	---	0.00	---	---
HMS	LOW	80	33.04	21.47	16.48	---	7.92	---	---
	MED	80	25.53	16.59	12.73	---	6.12	---	---
	HIGH	80	21.88	14.22	10.91	---	5.25	---	---
DRIP	LOW	60	---	13.25	---	---	---	---	---
	MED	60	---	11.10	---	---	---	---	---
	HIGH	60	---	9.12	---	---	---	---	---
LINEAR	LOW	85	28.42	---	14.17	8.52	6.81	---	---
	MED	85	22.38	---	11.16	6.71	5.37	---	---
	HIGH	85	20.82	---	10.38	6.24	4.99	---	---

Furrow Systems. Johnson (1988) and Taylor (1988) have indicated that normal furrow irrigation requires one man full time to irrigate two to three 160-acre fields. Taylor (1988) estimates that one quarter-section field will have 90 to 130 half-mile furrows irrigated at a time, with a typical flow rate of approximately 15 gpm per furrow.

Dimensional analysis illustrates that in 1 minute, one person can apply 2,700 to 8,100 gallons of water using furrow irrigation. This translates to the following range of unit time requirements:

- Low Management Level - minimum unit time requirement is 0.56 hour per acre-foot.
- Medium Management Level - average unit time requirement is 1.0 hour per acre-foot.
- High Management Level - maximum unit time requirement is 2.0 hours per acre-foot.

It is assumed that quarter-mile furrows will require approximately 60 percent more labor than half-mile furrows because water must be delivered to the heads of twice as many furrows to apply a desired volume of water to a quarter-section field.

For systems with tailwater return capability, it is assumed that the labor requirement is only 10 to 20 percent higher. This is based on the added time required to adjust the flow rates or number of furrows running as the return system adds to the delivery flow rate.

Labor requirements for low management levels are highest because these systems use labor-intensive siphon tubes. As management increases to the medium level, the unit time requirements drop 20 to 30 percent. As management increases to the high level, the labor rate increases slightly to reflect a higher degree of effort.

The labor requirements will be slightly different for the seven crop categories shown earlier. For the TFN category, the labor is assumed to be the least because these crops typically have widely spaced beds, resulting in fewer furrows needing attention. Conversely, the crops in the VEG category tend to have beds spaced closer together, which increases the unit labor requirements. The VEG and ROW crop categories have labor requirements between the two extremes, with the VEG crops requiring slightly more labor.

Border Strip Systems. Significantly less labor is required for border strip irrigation than for furrows because there are fewer delivery points on the field. To determine the range of unit labor requirements, it is assumed that one man can irrigate four to five fields at once and that the typical delivery to each field is approximately 3 to 4 cubic feet per second (cfs).

Dimensional analysis shows that the resulting unit labor requirement is 0.6 to 1.0 hour per acre-foot. As with furrows, the labor requirement is highest for the low management level because siphon tubes are relatively labor intensive, and the labor requirement for the high management level is slightly higher than for the medium level because the level of effort is expected to be greater.

It is assumed that the labor requirement will be slightly higher for TFN crops because these crops often have levees that are removed and replaced between each irrigation event, which requires slightly more labor.

Surge Control Furrow Systems. It is assumed that the labor requirements for low and medium management levels for surge-controlled furrows will be the same as those for medium and high levels for standard furrows. The operation of a surge system does not significantly differ from that of a standard grated system except for programming the surge valve. The level of effort required to program the surge valve is reflected in the labor rate (see Table 10).

The unit time requirements for the high management level are assumed to be the same as those for the medium level. A difference in level of effort is reflected in the labor rate.

Handmove Sprinkler Systems. The most labor-intensive element of handmove sprinklers is moving the laterals. To irrigate an entire field, each piece of lateral pipe must be moved approximately 10 times.

The typical discharge of a handmove sprinkler is approximately 3.8 to 5 gpm. A quarter-mile lateral with 44 sprinklers will apply approximately 0.39 acre-foot during a 12-hour set. Dei (1988) has indicated that a quarter-mile lateral takes approximately 1.5 hours to move. This results in a unit time requirement of approximately 3.0 to 4.1 hours per acre-foot.

The labor requirements for ALF, TFN, and ROW are considered to be the lowest since these crops have relatively deep root zones and set times can be long. The amount of labor required

Table 10
UNIT LABOR REQUIREMENTS (hr/AF)

IRRIG. TECH.	MGMT. LEVEL*	ALF	TFN	ROW	GRN	VEG	GRAS	POND
F2	LOW	---	1	1	---	1.3	---	---
	MED	---	0.8	0.8	---	1	---	---
	HIGH	---	0.9	0.9	---	1.2	---	---
F2-R	LOW	---	1.3	1.3	---	1.6	---	---
	MED	---	1	1	---	1.2	---	---
	HIGH	---	1.2	1.2	---	1.4	---	---
F4	LOW	---	1.6	1.6	---	1.8	---	---
	MED	---	1.2	1.2	---	1.4	---	---
	HIGH	---	1.4	1.4	---	1.6	---	---
F4-R	LOW	---	1.8	1.8	---	2.1	---	---
	MED	---	1.4	1.4	---	1.6	---	---
	HIGH	---	1.6	1.6	---	1.8	---	---
BORD	LOW	0.8	1	---	0.8	---	0.8	0.8
	MED	0.6	0.8	---	0.6	---	0.6	0.6
	HIGH	0.7	0.9	---	0.7	---	0.7	0.7
BORD-R	LOW	1.2	1.3	---	1.2	---	1.2	---
	MED	0.9	1	---	0.9	---	0.9	---
	HIGH	1	1.2	---	1	---	1	---
SURG-2	LOW	---	1	1	---	1.2	---	---
	MED	---	1.2	1.2	---	1.4	---	---
	HIGH	---	1.2	1.2	---	1.4	---	---
SURG-4	LOW	---	1.4	1.4	---	1.6	---	---
	MED	---	1.6	1.6	---	1.8	---	---
	HIGH	---	1.7	1.7	---	1.9	---	---
HMS	LOW	3	3	3	---	3.6	---	---
	MED	3.3	3.3	3.3	---	4	---	---
	HIGH	3.5	3.5	3.5	---	4.1	---	---
DRIP	LOW	---	0.1	---	---	---	---	---
	MED	---	0.2	---	---	---	---	---
	HIGH	---	0.25	---	---	---	---	---
LINEAR	LOW	0.15	---	0.15	0.15	0.15	---	---
	MED	0.2	---	0.2	0.2	0.2	---	---
	HIGH	0.25	---	0.25	0.25	0.25	---	---

for VEG crops will be higher because these crops have shallower root zones and set times must be shorter, and irrigation frequency will be higher.

Surface Drip Systems. The labor requirements for surface drip systems will be relatively small because these are often installed as turnkey systems. It is assumed that major labor demands will include filter flushing and operation, chlorination and fertigation, and checking for clogged emitters.

It is assumed that 2 hours will be required for filter flushing and 2 hours will be required to operate and maintain chlorination and fertigation equipment for each irrigation regardless of management level. These activities are assumed to be independent of management level because proper operation of this equipment is required to keep the system running.

The amount of time spent checking for plugged emitters will depend on the management level. It is assumed that for low management level, no time will be spent checking for and replacing plugged emitters. For medium and high management levels, it is assumed that 4 and 8 hours, respectively, will be required per each irrigation event.

The average drip systems will apply approximately 3 inches per irrigation, which results in a total application of 40 acre-feet to a 160-acre field.

Dimensional analysis shows that the sum of labor for each management level divided by the volume of application results in unit time requirements of 0.1, 0.2, and 0.3 hour per acre-foot for low, medium, and high management levels, respectively.

Linear Move Sprinkler Systems. A typical linear move installation will apply an average depth of approximately 0.33 inch to a field in one pass. This figure is based on typical peak ET requirements and losses, and results in a total application of approximately 9 acre-feet per pass.

It is estimated that approximately 2 to 3 hours of labor will be required for every pass of the machine. This labor will include servicing the machine, filling oil and fuel tanks, setting machine speed, travel time to the machine, and other miscellaneous tasks.

These figures relate to unit time requirements of from 0.2 to 0.3 hour per acre-foot. It is assumed that the lower labor figure will be required for low and medium management levels, and the higher labor will be used for high level management. Table 10 is a matrix of unit labor requirements.

Labor Rates

Labor rates are intended to reflect the requirement for higher skilled laborers to be employed under higher management levels. Farmers from the San Joaquin Valley were interviewed to determine realistic labor rates.

For a low management level, it is assumed that a transient, relatively unskilled laborer would be employed at minimum wage plus overhead. Raube (1988) and Gohring (1988) report that overhead rates for farm laborers are approximately 30 percent. This results in a low management labor rate of approximately $5.60/hour.

Raube (1988) and Darpinian (1988) have indicated that a semi-skilled laborer, with some training and the ability to learn some simple water-saving techniques (e.g., cutback furrow, etc.), will generally earn approximately $6/hour. At an overhead rate of 30 percent, the labor rate for medium-level management is approximately $7.80/hour.

For high-level management, it is assumed that the farm workers will typically be year-round employees who will learn irrigation techniques for a specified farm over time and use this experience to irrigate more efficiently. Dei (1988) and Darpinian (1988) have indicated that such an employee will typically earn approximately $7/hour, with an overhead rate of approximately 35 percent. Overhead for such an employee will be higher to reflect benefits associated with full-time employment. The overhead rate is based on the assumption that the full-time employee is involved in alternate, non-overhead tasks (e.g., farm machinery maintenance and repair, pruning, etc.) during off-season months. This results in a high management level labor rate of $9.50/hour.

Labor rates are shown in Table 11.

Total Labor Cost

The third component of labor cost is the volume of water applied to a field in a given year. The unit time requirement gives the number of man-hours per unit volume of applied water, and the labor rate gives the cost per man-hour for the labor.

The product of the unit time requirement, labor rate, and applied water gives the annual labor cost per acre for each crop, irrigation method, and management level (Table 12).

Table 11
LABOR RATES
BY MANAGEMENT LEVEL

Management Level	Labor Rate ($/hour)
Low	5.60
Medium	7.80
High	9.50

Table 12
ANNUAL LABOR COST ($/ac/yr)

IRRIG. TECH.	MGMT. LEVEL	ALF	TFN	ROW	GRN	VEG	GRAS	POND
F2	LOW	---	33.72	25.88	---	16.18	---	---
	MED	---	26.42	20.28	---	12.19	---	---
	HIGH	---	33.10	25.41	---	16.29	---	---
F2-R	LOW	---	37.94	29.12	---	17.23	---	---
	MED	---	29.77	22.85	---	13.18	---	---
	HIGH	---	40.65	31.20	---	17.50	---	---
F4	LOW	---	49.55	38.03	---	20.57	---	---
	MED	---	37.86	29.06	---	16.30	---	---
	HIGH	---	50.06	38.42	---	21.11	---	---
F4-R	LOW	---	47.10	36.15	---	20.28	---	---
	MED	---	39.99	30.69	---	16.86	---	---
	HIGH	---	52.14	40.02	---	21.65	---	---
BORD	LOW	41.51	33.72	---	12.44	---	13.94	67.70
	MED	29.57	25.62	---	8.86	---	9.93	48.22
	HIGH	34.66	28.96	---	10.39	---	11.64	56.52
BORD-R	LOW	50.04	35.23	---	15.00	---	16.80	---
	MED	40.10	28.96	---	12.02	---	13.46	---
	HIGH	46.61	36.35	---	13.97	---	15.65	---
SURG-2	LOW	---	26.17	20.08	---	11.59	---	---
	MED	---	34.28	26.31	---	14.76	---	---
	HIGH	---	39.11	30.02	---	16.84	---	---
SURG-4	LOW	---	32.19	24.71	---	13.58	---	---
	MED	---	43.36	33.28	---	18.00	---	---
	HIGH	---	50.31	38.61	---	20.75	---	---
HMS	LOW	137.36	89.27	68.52	---	39.53	---	---
	MED	162.63	105.69	81.12	---	47.27	---	---
	HIGH	180.07	117.02	89.82	---	50.58	---	---
DRIP	LOW	---	2.45	---	---	---	---	---
	MED	---	5.71	---	---	---	---	---
	HIGH	---	7.15	---	---	---	---	---
LINEAR	LOW	5.56	---	2.77	1.67	1.33	---	---
	MED	8.13	---	4.06	2.44	1.95	---	---
	HIGH	11.52	---	5.74	3.45	2.76	---	---

ADMINISTRATIVE COSTS

The cost of administering irrigation is difficult to quantify. For this study, administration cost is defined as the cost of scheduling and implementing irrigation for the three management levels.

Scheduling Costs

Irrigation scheduling tasks include determining the best time to irrigate and the appropriate amount of water to apply at each irrigation.

Scheduling of irrigation for a high level of management will involve collecting ET and soil moisture data. The high management level will require preparation of a water balance and annual leaching requirements. A high-level manager must have some knowledge of irrigation scheduling, such as practices of irrigation frequency and optimum volume of water applied. This level of management also assumes that the manager will spend a significant amount of time educating the farm irrigators about efficient irrigation methods.

A medium level of management will require a simple determination of crop water use by historical ET measurements or local crop water guidelines (Westlands Water District, 1984). The medium-level manager will spend much less time educating irrigators about efficient practices.

For a low level of management, it is assumed that irrigation scheduling will be a very cursory effort. A minimal scheduling effort will involve looking at a calendar and planning irrigation dates based on convenience or experience. The low-management level irrigator will receive little or no instruction concerning good irrigation practices.

To estimate the cost of irrigation scheduling, three commercial scheduling companies were interviewed. Briner (1988) reported that irrigation scheduling service will cost $1,700 to $2,000 per year for a 90- to 160-acre field regardless of the crop grown. Braise (1988) has indicated that irrigation scheduling costs approximately $9 per acre, but that irrigation scheduling is seldom sold without some other production or management service included. Rathbun (1988) estimated that irrigation scheduling service will cost $6 to $20 per acre, with the $6-per-acre price the most common.

The irrigation scheduling services polled provide varying degrees of technical analysis as part of their scheduling preparation. The lower priced services reflect the tasks assumed to be included as medium level management activities, while the most expensive services provide the type of detailed analysis assumed for high management levels.

Based on the costs listed above, irrigation scheduling is assumed to cost approximately $16 per acre for high management level, $8.50 per acre for medium level management, and $1 per acre for low level management.

The medium and high management level scheduling costs reflect the expense of hiring a professional irrigation scheduler. It is assumed that the cost to a farmer will be approximately the same whether a scheduling service is hired or the farmer does the scheduling himself. This assumption is based on the supposition that a farmer will have to subscribe to some sort of water use information source and invest time and money each year to continue his education concerning irrigation scheduling practices.

Implementation Costs

Irrigation implementation tasks include hiring and educating irrigators, purchasing and coordinating maintenance of equipment, and ordering water from the irrigation district. Annual farm management costs have been estimated at $55 per acre (CH2M HILL, 1988). It is assumed that irrigation implementation cost is approximately one-seventh of this cost.

Given the above definition of irrigation implementation, implementation cost is assumed to be relatively constant for all management levels because these tasks are required for any irrigation event to take place and for water to be delivered to a field. Based on these assumptions, the cost of implementation is estimated at $8.00, $7.50, and $7.00 per acre per year for high, medium, and low management levels, respectively.

Combined Costs

The combined irrigation administration costs are the sum of the scheduling and implementation costs given above (Table 13).

COMPARISON OF TOTAL COSTS

Table 14 summarizes the total annual costs of the irrigation systems. Each of the cost categories presented has been expressed in dollars per acre per year. These costs can be combined to give total costs for each combination of crop, method, and management level. The total cost for each crop/system/management level combination is the sum of the corresponding capital cost (Table 6), maintenance cost (Table 6), pumping cost (Table 9), labor cost (Table 12), and administrative cost (Table 13). Appendix C gives an example of the total cost computation.

Table 13
IRRIGATION ADMINISTRATION COSTS
($/ac/year)

Type of Cost	Management Level		
	Low	Medium	High
Scheduling	1.00	8.50	16.00
Implementation	7.00	7.50	8.00
Total	8.00	16.00	24.00

Table 14
TOTAL COST ($/ac/yr)

IRRIG. TECH.	MGMT. LEVEL	ALF	TFN	ROW	GRN	VEG	GRAS	POND
F2	LOW	---	44.61	36.77	---	27.06	---	---
	MED	---	63.48	57.34	---	49.24	---	---
	HIGH	---	80.16	72.46	---	63.34	---	---
F2-R	LOW	---	74.68	65.86	---	53.97	---	---
	MED	---	94.18	87.26	---	77.59	---	---
	HIGH	---	116.56	107.11	---	93.41	---	---
F4	LOW	---	63.55	52.03	---	34.57	---	---
	MED	---	104.80	96.00	---	83.24	---	---
	HIGH	---	128.50	116.86	---	99.55	---	---
F4-R	LOW	---	86.94	75.99	---	60.12	---	---
	MED	---	134.28	124.98	---	111.15	---	---
	HIGH	---	159.43	147.31	---	128.93	---	---
BORD	LOW	52.85	45.06	---	23.78	---	25.28	79.04
	MED	98.84	94.90	---	78.14	---	79.20	117.49
	HIGH	113.64	107.94	---	89.37	---	90.61	135.50
BORD-R	LOW	87.23	72.42	---	52.19	---	53.99	---
	MED	136.73	125.58	---	108.65	---	110.09	---
	HIGH	154.43	144.17	---	121.80	---	123.47	---
SURG-2	LOW	---	90.58	84.50	---	76.00	---	---
	MED	---	109.50	101.53	---	89.98	---	---
	HIGH	---	126.22	117.13	---	103.95	---	---
SURG-4	LOW	---	117.47	109.99	---	98.86	---	---
	MED	---	139.84	129.76	---	114.48	---	---
	HIGH	---	159.79	148.09	---	130.23	---	---
HMS	LOW	255.04	195.38	169.64	---	132.09	---	---
	MED	284.20	218.32	189.89	---	149.44	---	---
	HIGH	309.99	239.28	208.77	---	163.87	---	---
DRIP	LOW	---	284.36	---	---	---	---	---
	MED	---	304.88	---	---	---	---	---
	HIGH	---	320.64	---	---	---	---	---
LINEAR	LOW	165.38	---	148.35	141.58	139.55	---	---
	MED	177.91	---	162.62	156.55	154.72	---	---
	HIGH	195.83	---	179.63	173.19	171.25	---	---

The irrigation method with the highest costs is handmove sprinklers. The costs for all of the pressurized systems do not differ greatly with management level. For the surface irrigation methods, the total costs for low management are up to 70 percent less than those for higher management levels.

APPENDIX A

Appendix A
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APPENDIX B

Appendix B
DATA SOURCES FOR IRRIGATION SYSTEM COMPONENT COSTS

1) Aanonson Sprinkler Co., Madera, CA. 209/673-4261. December 1987.

2) Agri-Valley Irrigation Co., Fresno, CA. 209/486-1412. December 1987.

3) C & W Irrigation, Bakersfield, CA. 805/831-9579. July 1988.

4) S.A. Camp Pump Company, Bakersfield, CA. 805/399-2976. July 1988.

5) Drip-In Irrigation Co., Fresno, CA. 209/275-1223. December 1987.

6) Fresno Valves and Castings, Inc., Selma, CA. 209/834-2511. December 1987.

7) Farm Pump & Irrigation Co. Inc., Shafter, CA. 805/589-6901. July 1988.

8) O'Neal Irrigation Supply Co., Fresno, CA. 209/431-9220. December 1987.

9) Rain for Rent, Inc., Fresno, CA. 209/485-5610. December 1987.

10) J & L Irrigation, Fresno, CA. 209/237-2181. December 1987.

11) Blacks Concrete Pipe Co., Chowchilla, CA. 209/665-4891. December 1987.

12) Valley Trenching, Clovis, CA. 209/299-0807. December 1987.

13) Water-Ways Irrigation Engineers Inc., Bakersfield, CA. 805/831-3535. December 1987.

14) Hydratec Inc., Delano, CA. 805/725-6656. December 1987.

15) Golden State Irrigation. Stockton, CA. 209/943-7774. January 1988.

16) Lance Johnson, Senior Engineer, Westlands Water District, Fresno, CA. 209/224-1523. January 1988.

17) Charles Burt, Professor of Agricultural Engineering, California Polytechnical State University, San Luis Obispo, CA. 805/756-2379. July 1988.

18) CH2M HILL, Inc., Santa Rosa, CA. Santa Rosa Land Application System Project Files, Project No. F19445.A0. October 1986.

19) CH2M HILL, Inc., Santa Rosa, CA. Santa Rosa Land Application System Project Files, Project No. F19445.A0. July 1985.

20) Mike Grundvig, Senior Engineer, Western Oilfield Supply Co., Bakersfield, CA. 805/399-9124. January 1988.

21) Larry Isheim, Head Engineer, HP Metzler & Sons, Fresno, CA. 209/445-1574. February 1988.

APPENDIX C

Appendix C
TOTAL COST COMPUTATION EXAMPLE

Crop: ROW (Row crops)

Technology: F4-R (Furrows, 1/4-mile runs, with return)

Managment Level: Medium

Capital Cost

Delivery System Cost = $46.24/ac/yr (from Table 3d; entered in Table 6, column 3)

Return System Cost = $24.65/ac/yr (from Table 31; entered into Table 6, column 4)

Total Capital Cost = $46.24/ac/yr + $24.65/ac/yr = $70.89/ac/yr (entered into Table 6, column 5)

Maintenance Cost

Delivery System Maintenance Percentage = 1.5%/yr (page 20, paragraph 2)

Capital Cost of Gated Pipe = $247/ac (Table 3d)

Delivery System Maintenance Cost =

$$\frac{1.5\%/yr}{100} \times \$247/ac = \$3.70/ac/yr$$ (entered into Table 6, column 6)

Land Grading = $1.00/ac/yr (from page 21, paragraph 3; entered into Table 6, column 7)

Return System Maintenance Cost = $2.70/ac/yr (from page 21, paragraph 5; entered into Table 6, column 8)

Total Maintenance Cost = $3.70 + $1.00 + $2.70 = $7.40/ac/yr (entered into Table 6, column 9)

Combined Capital and Maintenance Cost = $70.89 + $7.40 = $78.29/ac/yr (entered into Table 6, column 10)

Pumping Cost

Pumping Cost = $0.00/ac/yr (from Table 9)

Labor Cost

Applied Water = 2.81 ac-ft/ac/yr (from Table 8, column 5)

Unit Labor Requirement = 1.4 hr/ac-ft (from Table 10, column 5)

Labor Rate = $7.80/hr (from Table 11)

Annual Labor Cost = 2.81 ac-ft/ac/yr x 1.4 hr/ac-ft x $7.80/hr = $30.69/ac/yr (entered into Table 12, column 5)

Administration Cost

Scheduling Cost = $8.50/ac/yr (from page 35, paragraph 1)

Implementation Cost = $7.50/ac/yr (from page 36, paragraph 4)

Administration Cost = $8.50 + $7.50 = $16.00/ac/yr (entered into Table 13)

Total Cost

Capital and Maintenance Cost = $78.29/ac/yr (Table 6, column 10)

Pumping Cost = $0.00/ac/yr (Table 9)

Labor Cost = $30.69/ac/yr (Table 12, column 5)

Administration Cost = $16.00/ac/yr (Table 13)

Total Cost = $78.29 + $0.00 + $30.69 + $16.00 = $124.98/ac/yr (entered into Table 14, column 5)